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Peter Love
Edith Cowan University

Craig Standing
Edith Cowan University

Rosemary Stockdale
Edith Cowan University

Zahir Irani
Brunel University

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An Ex-Ante Information Technology Evaluation Framework for Construction Organizations: The First Step Toward Gaining a Competitive Advantage

Peter Love¹, Zahir Irani² and Hosein Gharavi¹

¹School of MIS, Edith Cowan University, Perth, WA

²Department of Information Systems and Computing, Brunel University, UK

Abstract

Within the construction industry issues surrounding the IT investment process remain largely unexplored. To address this aforementioned deficiency, a questionnaire survey was undertaken to examine the approaches used by construction organizations to evaluate and justify their IT investments. The analysis of 126 responses revealed the following key findings: different types of organization significantly differ in the amount they invest in IT; investment levels in IT were not influenced by organizational size; and the scope of purpose of ex-ante IT evaluation was considered broader than a financial control mechanism. Instead, the organizations sampled used ex-post evaluation as an opportunity for learning and thus regenerated knowledge. Based on these findings a pragmatic ex-ante IT evaluation framework is proposed which can be used by construction organizations to ameliorate their investment decision-making process.

KEYWORDS: Appraisal techniques, evaluation, information technology, investment

INTRODUCTION

The evaluation of information technology (IT) has received considerable attention in the information systems (IS) and business management literature (Irani and Love, 2001) and it is widely recognised that evaluation is critical for the *successful* adoption and implementation of IT (eg, Anandarajan and Wen, 1998). Many construction organizations, however, have reported that they are unaware of a generic methodology that can be used to justify their IT investments (Love *et al.* 2004). The emergences of e-business, enterprise wide applications and mobile commerce technologies have added to the complexity associated with their evaluation, and as a result, have made it difficult for managers to articulate their benefits and prove an immediate return on investment. Despite such difficulties, the need to undertake evaluations of IT exists (i.e. ex-ante, ex-post, formative and summative) so that benefits management process and the technology's effectiveness can be translated into favourable outcomes for the organization and its respective stakeholders. Moreover, such evaluations provide a control loop of invaluable feedback which in-turn allows the performance of technology employed to be readily judged over its life-cycle. There is an implicit assumption amongst some construction management researchers that the adoption of IT is a panacea to the problems of sustaining a construction organization's competitive advantage as well as the industry's overall performance. This presupposition is erroneous (Li *et al.*, 2000) because the evaluation of an IT project's lifecycle is necessary to determine whether the technology is an investment sinkhole (specifically, should the project be concluded to minimize any further additional capital outlay) or an appropriate investment for the organization (Willcocks and Lester, 1997; Willcocks and Graeser, 2001; Irani *et al.* 2003). As IT applications are becoming an obligatory resource required to sustain the well-being of construction organizations, their justification and evaluation require serious consideration. In this paper, IT evaluation investment practices adopted within Australian construction organizations are examined. Findings emanating from the research work are then used to develop a framework to assist construction organizations (i.e., architects, quantity surveyors, contractors etc) with the process of IT evaluation.

INVESTMENT IN IT

Information technology investments differ in nature from other capital investments as there is a substantial human and organizational interface (Irani *et al.*, 2003). Such investments can be high risk as they often manifest themselves as erratic timing of cash-flows and significant intangible costs (Milis and Mercken, 2004). Despite these potential financial problems IT capital investments are frequently evaluated using traditional appraisal techniques as adopted within the property sector. These traditional methods are suitable for capital investments where the fixed asset has a long term resale value that often appreciates with inflation. For IT investments however, the converse is true since the exponential rate of technological development renders IT resources obsolete in a far shorter duration (Primrose, 1991).

There are a myriad of reasons why organizations should appraise their IT investments, these include (Irani and Love, 2002):

- comparison between different IT projects so as to determine those that are going to add value to the organization's strategic positioning;
- ranking of projects in terms of organizational priorities;
- justify investment requests by management;
- control expenditure, benefits, risk, development and implementation of projects; and
- provide a framework that facilitates organizational learning.

Primrose (1991) noted that many managers negatively viewed project appraisal as a financial hurdle *vis-à-vis* a useful technique for evaluating a project's worth.

Information technology project investments often involve multiple stakeholders and increasingly impact upon the organization's supply chain. According to Milis and Mercken (2004), there are typically five core parties involved with the IT investment process; each having their own set of objectives and expectations. For financial based evaluations using traditional appraisal techniques, the process only serves the objective of management and thus neglects all other parties' objectives (such as project team members and users). In turn, critical factors that might affect the willingness of these parties to cooperate in realising the objectives of the investment are not incorporated into the investment decision-making process.

Choosing an evaluation approach that reaches beyond the traditional boundaries of financial evaluation (for example, direct cost analysis and cash flow projections) is increasingly important, and many factors associated with developing a robust IS requires a business, user and technology context. The fact that financial transparency is paramount so as to ensure a suitable return on investment), other strategically softer, political and social factors need to be considered during the evaluation process. A comprehensive list of investment appraisal approaches can be found in Renkema and Berghout (1997), Irani and Love (2002), and Mills and Mercken (2004). Several predominant generic ex-ante evaluation methods (and techniques within each method) used to justify capital investments in IT are identified in Table 2; these methods are traditional evaluation, adjusted traditional evaluation, new evaluation techniques and mixed evaluation methods.

Table 1. Milis and Mercken's (2004) ex-ante evaluation techniques

Appraisal method	Techniques
<i>Traditional evaluation methods</i>	Payback period Return on investment (ROI) Internal rate of return (IRR) Net present value (NPV)
<i>Adjusted traditional evaluation methods</i>	Adjusted cost/benefit analysis Discount rate sensitivity Adjusted interpretation process
<i>New evaluation techniques</i>	Strategic fit Information economics The options model
<i>Mixed evaluation methods</i>	Multi-layer evaluation process Balanced scorecard

A further perspective is a move away from *generic* appraisal techniques to *sympathetic* techniques where IT evaluations are based on bespoke project characteristics. For example, Hochstrasser (1990) classified IT projects based on their objectives:

- *Infrastructure projects*: Hardware or software systems installed to enable the subsequent development of front-end systems;
- *Cost replacement projects*: IT systems introduced to automate manual activities;
- *Economy of scale projects*: Systems introduced to allow a company to handle an increased volume of data;
- *Economy of scope projects*: IT systems introduced to allow a company to perform an extended range of tasks;
- *Customer support projects*: IT systems introduced to offer better services to customers;

- *Quality support projects*: IT introduced to increase the quality of the finished product;
- *Information sharing and manipulation projects*: IT systems introduced to offer better information sharing and information manipulation; and
- *New technology projects*: IT systems introduced to exploit strategically the business potential of the new technology, to do things that were not possible before.

Hochstrasser (1990) suggests that a particular appraisal technique should be matched to one of the above project characteristics. For example, if the project were a *cost replacement project* (where costs are direct in nature and perceived benefits largely efficiency gains), then the investment could be evaluated using traditional economic appraisal approaches such as, ratio based or discounted approaches. Alternatively, for *new technology project* investment which include a strategic dimension and substantial intangible benefits and indirect costs, then approaches like the balanced score card might well be more appropriate (e.g., Stewart and Mohamed, 2002; Stewart and Mohamed, 2003).

RESEARCH METHODOLOGY

A thorough literature review revealed that a notable dearth of construction industry IT evaluation studies (eg, Li, 1996; CIRIA, 1996; Construct IT, 1998; Atkin *et al.*, 1999; Baldwin *et al.*, 1999; Andresen *et al.*, 2000; Marsh and Flanagan, 2000; Love *et al.*, 2000; Irani and Love, 2001; Stewart and Mohamed, 2003; Love *et al.*, 2004a). To address this deficiency, the IT evaluation practices of various organization types (such as, architects, consulting engineers, consulting project managers, quantity surveyors (QS) and contractors) were examined using a questionnaire survey. The fundamental purpose of the questionnaire was to determine the IT investment practices that are implemented by organizations in the construction industry.

Questionnaire survey

The population of participants was extracted from the telephone directory 'Yellow Pages' and selected using stratified random sampling. A pilot study was first undertaken to measure the potential response rate and inherent suitability of the questionnaire developed using a sub-sample of 25 selected organizations. Various professional occupations were represented including architects, consulting engineers, consulting project managers, contractors and QSs. Speculative telephone interviews were conducted to obtain the each organization's commitment to the research work prior to posting a package of information which contained the questionnaire and stamp addressed 'return' envelope. Such an approach ensured that a 100% response rate was obtained. Importantly, respondents were invited to actively participate in the work by providing constructive comments on the design and structure of the survey. At the end of this consultation process, all comments received were positive and therefore the decision was taken to post an unadulterated copy of the original questionnaire to the main sample participants. Having successfully concluded the pilot work, the main survey work was then commenced and consisted of 50 questionnaires mailed to each of the five aforementioned organization types throughout Australia. Of the 250 questionnaires posted, 101 valid responses were received from the main survey, which when added to the 25 'unchanged' pilot questionnaires gave a total of 126 valid responses; representing a total consolidated response rate of 45%.

FINDINGS

Sample characteristics

Figures 1 and 2 provide a breakdown of the valid respondent responses by organization type and geographical State. The sample is considered to be a reasonable representation of the Australian construction industry's IT investment practices, considering its low up-take of IT. Figures 3 and 4 provide details about the sample's distribution in terms of the organization's number of employees and the turnover. Of the 126 organizations, 75% employed less than 30 employees and 79% had a turnover less than \$A10 million. Thus, most of the sample was comprised of small and micro organizations.

It was found that 93% of construction contractors invested less than 1% of their turnover on IT, whereas over 50% of the other organizations sampled invested between 1% and 5% of their turnover. 90% of the organizations surveyed invested less than 5% of their turnover on IT, with 44% investing less than 1%. Only 10% of organizations sampled invested more than 5% of their turnover in IT and notably, most of these were architects and QSs. The ANOVA revealed that investments in IT did not significantly vary with firm size (turnover and number of employees) ($p < 0.05$). However, differences in IT investments were found between organization types, $F(4, 126) = 10.48$, ($p < 0.05$). A Tukey's *honestly significant difference* (HSD) post hoc test was undertaken but did not identify differences between organizations ($p < 0.05$). Thus, investments in IT

have not increased despite the widespread use of e-business and e-commerce applications throughout the Australian economy.

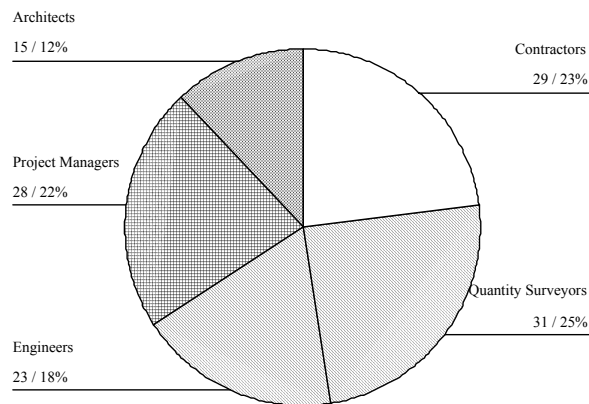


Figure 1. Respondents by organization type

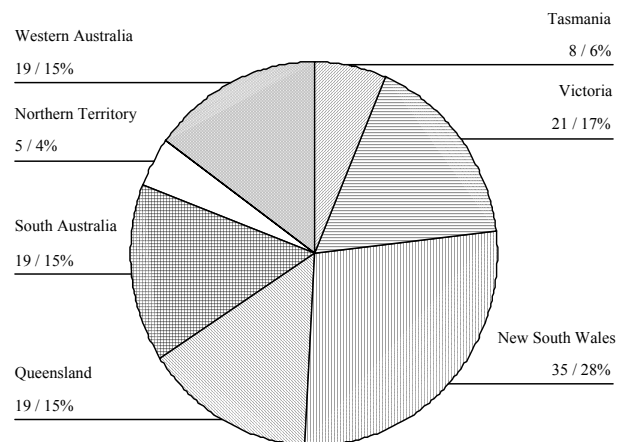


Figure 2. Respondents by State

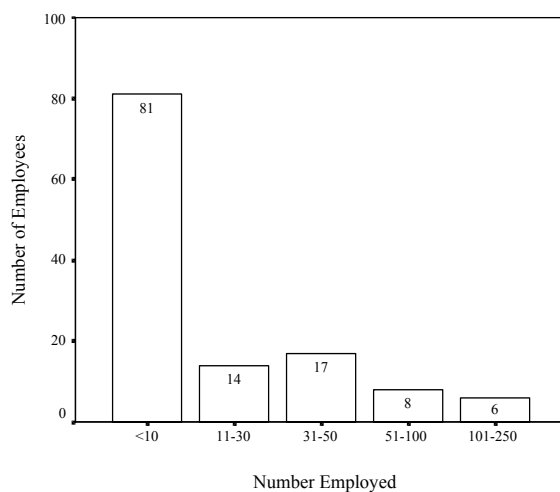


Figure 3. Firm size by number of employees sampled

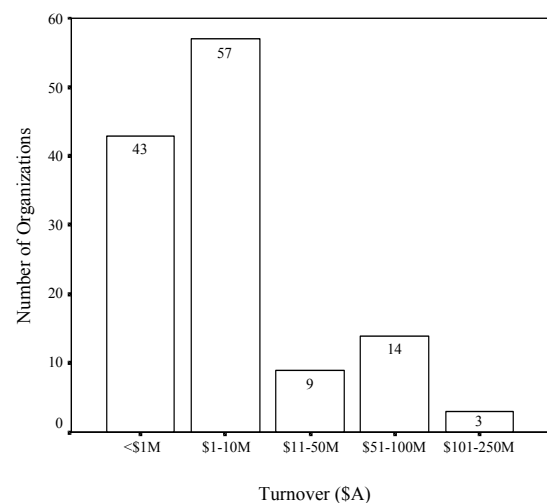


Figure 4. Turnover of organizations sampled

Evaluation approaches

Only 40% of organizations sampled used an investment technique to evaluate their IT investments. Anecdotal evidence would suggest that this finding is not due to a lack of knowledge of the available techniques; instead, it is apparent that IT does not form an integral part of their business strategy for competitive advantage. At a tactical and operational level, however, IT is being increasingly used throughout the construction industry. The emergence of e-business applications, however, for the procurement of materials (Kong *et al.*, 2001) and sharing information between project participants (Elliman and Orange, 2000) are beginning to be embraced by some construction organizations. The adoption and implementation of the technology requires significant capital outlay at the outset, and on a continual basis as technology develops. As a result, ex-ante evaluation will have to form an integral part of their IT management strategy if organizations are to remain competitive. From the findings presented, it would appear that the construction organizations sampled are less likely to adopt a formal

ex-ante evaluation process. According to Ballantine *et al.* (1996b) traditional financial techniques are more appropriate for evaluating IT investments in small-to-medium than larger organizations.

Over 50% of organisations sampled prepare an IT benefits delivery plan prior to, and during, system design and implementation. There is considerable divergence in the use of formative evaluation processes within the sample. A Kruskal-Wallis test was undertaken to determine if any significant differences between the size of the organization, the organization type, and the evaluation processes employed exist. In the case of turnover, there were significant differences between turnover and all evaluation processes employed with the exception of the 'use of IT to develop future processes' ($\chi^2 = 7.06, p < 0.13$). This implies that when construction organizations do implement IT, they aim to utilize its value adding potential. There were also significant differences between the number of people employed and all of the evaluation process adopted ($p < 0.05$). However, no significant differences between organization types where evaluation processes adopted were identified ($p < 0.5$). The size of the organization (in terms of employees employed) therefore influences the extent of evaluation processes implemented. Ballantine *et al.* (1996b) proposed that small-to-medium sized firms were more likely to focus on control of their investment rather than learning from its implementation. However, it would appear that predominantly, the evaluation process is used by construction organizations as both a control and learning mechanism, even though it may not form an integral part of their business strategy.

A significant proportion of the organizations sampled indicated that some difficulty was encountered when determining their IT investment, particularly the need to demonstrate quick financial returns. Significant differences between turnover and the justification inhibitors were identified for the following variables:

- 'limited managerial and technological knowledge' ($\chi^2 = 20.77, p < 0.00$);
- 'lack of strategic vision' ($\chi^2 = 29.49, p < 0.00$); and
- 'reluctance of employees to adapt to new technology' ($\chi^2 = 18.15, p < 0.01$).

There was also significant difference between the number of people employed and justification inhibitors for the following variables:

- 'inability to select an appropriate IT appraisal technique' ($\chi^2 = 11.06, p < 0.02$)
- 'lack of strategic vision' ($\chi^2 = 14.79, p < 0.05$); and
- 'an ability to account for the full business benefits' ($\chi^2 = 10.84, p < 0.02$).

Several differences with respect to the organizational size and organization types were identified: Those identified were:

- 'limited managerial and technological knowledge' ($\chi^2 = 18.99, p < 0.01$);
- 'lack of strategic vision' ($\chi^2 = 11.69, p < 0.02$);
- 'unable to identify financial benefits' ($\chi^2 = 11.69, p < 0.01$);
- 'an ability to account for the full business benefits' ($\chi^2 = 17.83, p < 0.01$);
- 'reluctance of employees to adapt to new technology' ($\chi^2 = 22.15, p < 0.00$); and
- 'inability to select an appropriate IT appraisal technique' ($\chi^2 = 11.63, p < 0.02$).

Considering the evidence provided, a lack of strategic vision is a key factor inhibiting the justification process for organizations. As construction organizations now need to embrace IT to gain a competitive advantage, it is expected that they will begin to evaluate their investments in a more systematic and structured manner.

Motivations for IT adoption

The analysis revealed that the primary organizational drivers for IT implementation were improvements to productivity (cost efficiency) and business processes. To gain a competitive advantage, the improvement of service quality and firm profitability were also identified as primary motivations for IT adoption. Over 70% of the organizations suggested that a motivation for adopting IT was to support the strategic direction of the organization. Differences were found between the number of people employed and motivation factors, with the exception of 'to gain a competitive advantage' ($p < 0.05$). With respect to turnover, the only significant differences were with 'support the strategic direction of the organization' ($\chi^2 = 18.07, p < 0.01$) and 'improve service quality' ($\chi^2 = 17.75, p < 0.01$). Noteworthy, the only significant difference between organization types for motivation factors was 'to improve service quality' ($\chi^2 = 13.83, p < 0.00$). Information technology applications can be used for an array of services provided by construction organizations. For example, at an operational level, Computer Aided Design (CAD) often improves the quality of contract documentation,

especially when design professionals integrate and coordinate their outputs. This appears to be a relatively straightforward process, but cultural and behavioural barriers, juxtaposed with problems associated with interoperability have hindered the production of effective contract documentation. In turn, an adverse affect on the service quality of organizations is experienced (Love *et al.* 2004b).

AN IT EVALUATION EX-ANTE FRAMEWORK

The evaluation methods that are used by the construction organizations sampled neglect to address the complexity associated with IT decision-making process. In addition, they do very little in the way of providing management and stakeholders a true reflection of the investments total costs because only tangible costs are taken into account, which only account for a fraction of total costs experienced in an investment's life cycle (eg. Farbey *et al.*, 1993). Discounted cash flow techniques such as net present value (NPV) and internal rate of return (IRR) are used to:

- essentially estimate and evaluate cash flows;
- recognise and discount for the time value of money;
- establish whether incremental benefits exceed incremental costs; and
- provide a figure that indicates project viability.

While a plethora of methods for justifying IT investments have been developed (Irani and Love, 2002), no single technique can cope with the wide range of circumstances in which IT may be required (Farbey *et al.*, 1993; Anandarajan and Wen, 1999). Rather than using a technique that focuses on tangible benefits and costs it is important that an evaluation method also takes into account both the intangible benefits and costs associated with IT adoption. Rather than deviating from current practice, and developing a new technique that requires a significant change to organizational mindset, a pragmatic framework that can readily used by construction organization is proposed Figure 5. Baldwin *et al.* (1999) have proposed a similar framework but with the significant difference that the quantification of indirect benefits and costs is not taken into account. Furthermore, potential benefits are examined from an efficiency, effectiveness and performance perspective. These are relatively meaningless taxonomies because they are in fact interrelated and difficult to operationalise in a process. Thus, it is suggested that business process such as those proposed by Baldwin *et al.* (1999) (see Figure 5) be analysed in terms of the technologies contribution to an organization's strategic, tactical and operational levels of a process. This can enable an organization to isolate specific IT contributions in terms of benefit and cost, specifically those of an intangible nature. In fact, the most significant intangible benefits/costs that occur in organizations are those at the strategic level (Irani and Love, 2002).

Instead of the decision to invest in IT being taken by an accountant or management, it is suggested that key stakeholders be actively involved in the justification process, especially since intangible benefits of an IT investment are difficult to determine. The expected value of benefits can be determined using probabilities for different scenarios and computing expected values for each of the processes identified, which in turn can be used to establish the probability of savings to be made (Anandarajan and Wen, 1999; Baldwin *et al.*, 1999). Alternatively, the opportunity cost could be determined by examining the amount of time that can be saved from implementing the technology and/or application. For example, during the construction production process a contractor could use mobile applications to conduct real-time health and safety reviews and thus reduce the time to rectify hazards and eliminate the possibility of accidents. The hypothetical intangible monetary benefits that could materialise from utilising such technology are identified in Table 2.

If a contractor was to implement an enterprise wide application such as enterprise resource planning (ERP), then benefits would need to be determined for all the business functions and process levels (Figure 5). This represents a time-consuming but worthy process considering the significant capital outlay that would be required to implement this type of application. The determination of direct costs is a relatively straightforward process. The taxonomy of IT costs proposed in Irani *et al.* (2004) can be used as a reference point for identifying those costs that are likely to be incurred during an IT project's lifecycle. Once the NPV, IRR and payback are determined for the direct and indirect costs that have been identified, *sensitivity analysis* should be undertaken to take account for any errors that could be contained in the forecasts. As a result, the factors that affect the cost adopting IT can be identified. The risks associated with the adoption of IT and its mitigation should be identified. Factors that might lead to the failure of an IT project include, lack of alignment to organizational strategy, lack of organizational adaptation to complement technological change, too much faith in a technical fix and poor management of change (Willcocks and Graeser, 2001).

Figure 5 An IT investment frameworks for construction organizations

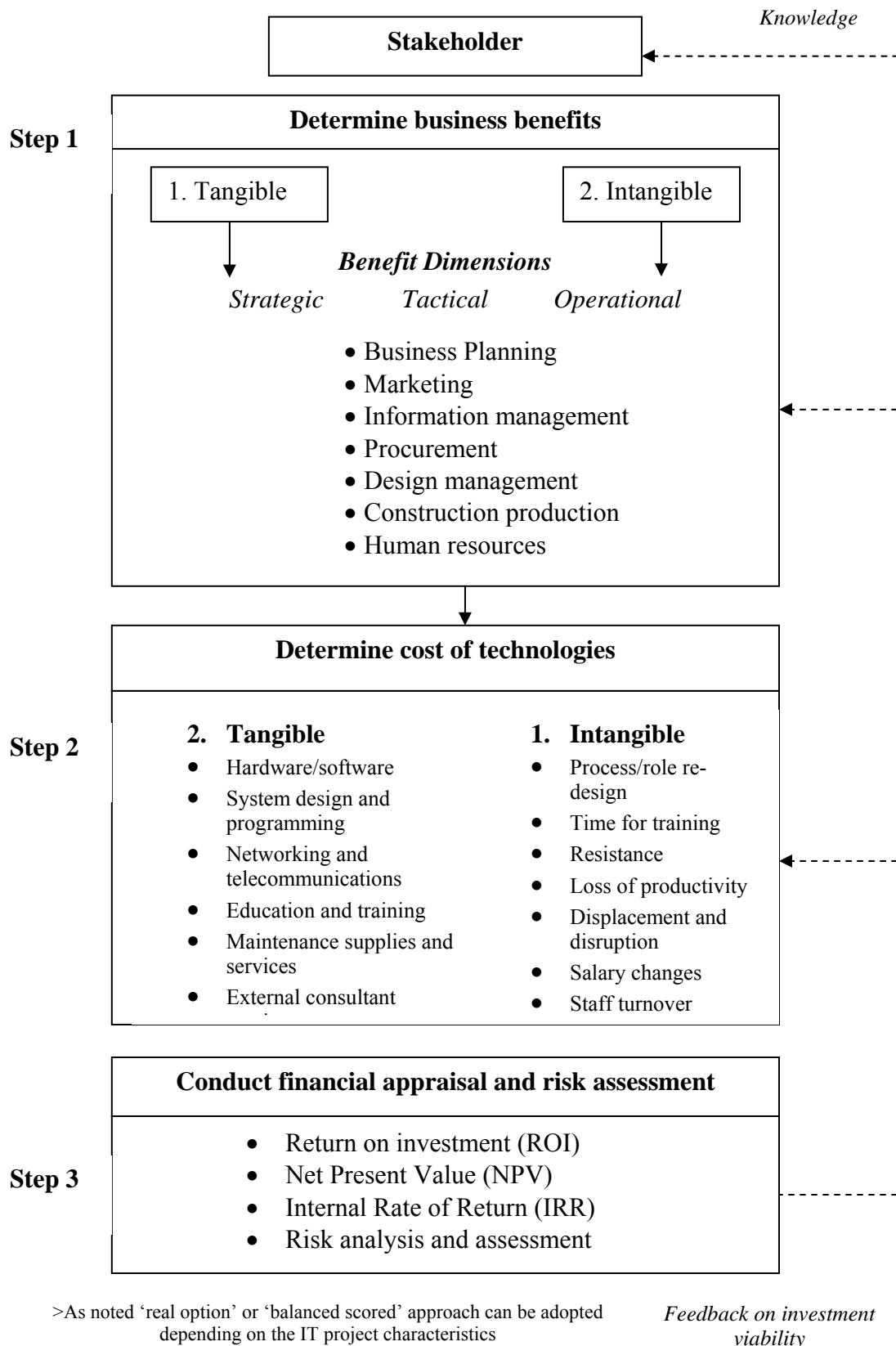


Table 2. Example of expected value of intangible benefits

Possible reduction in administrative time over a month (hours)	Probability of occurrence	Mid-point of anticipated increase	Incremental savings (Col 3 x \$200 average saving per hour)	Probability of savings (Col 2 x 4)
0	0	-	0	0
1-5	3	2.5	\$500	\$1 500
6-10	5	7.5	\$1 500	\$7 500
11-20	10	15.5	\$3 100	\$31 000
21-30	5	25.5	\$5 100	\$25 500
31-40	4	35.5	\$7 100	\$28 400
41-50	3	45.5	\$9 100	\$27 300
				\$121 200

Note: This is a hypothetical example and the figures reported are only used to demonstrate the determination of an intangible benefit. Also, note the savings associated with the site not being closed/or no access to a work area have not been included here. Only the time of the persons responsible for conducting safety audits etc is considered.

CONCLUSION

Evidence provided in this paper suggests that the evaluation of IT is an area that Australian construction organizations have neglected, even though significant a proportion of those sampled suggested that they had implemented IT for strategic reasons. Discounted cashflow methods were the primary methods being used by the sampled construction organizations to evaluate their IT investments. Yet, the research revealed that a considerable proportion of the sample did not undertake any form of financial evaluation of their IT investments. Based on the findings presented a pragmatic framework that can be used to guide construction organizations through the ex-ante evaluation process for an IT investment was proposed. The framework takes into account the importance of stakeholders in the evaluation exercise and proposes that the initial business benefits to be expected from implementing IT are determined from a *strategic, tactical and operational* perspective. Once this has been undertaken tangible and intangible costs should be identified and then financial appraisal and risk assessments undertaken. Implementation of the framework does not require any significant change to business practices, though it does require organizations to provide greater attention to the justification process by placing emphasis on tangible and intangible benefits/costs of their potential investment. The problems associated with IT investment evaluation are complex, but it is hoped that the framework that has been propagated provides construction organizations with the foundation to better understand the implications of their investments in IT.

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